



**NOAA
FISHERIES**

**Alaska
Fisheries
Science
Center**

NMFS Climate Science Strategy

Southeastern Bering Sea

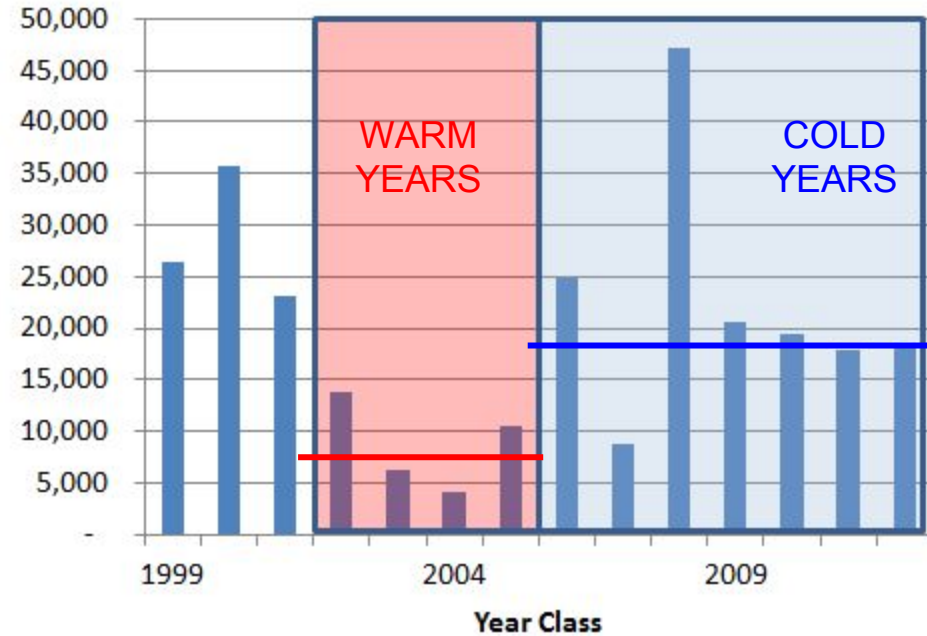
Mike Sigler, Alan Haynie, Amber Himes-Cornell, Anne
Hollowed, Phil Mundy, Phyllis Stabeno, Stephani Zador, Steve
Davis, Brandee Gerke

Climate and Fisheries

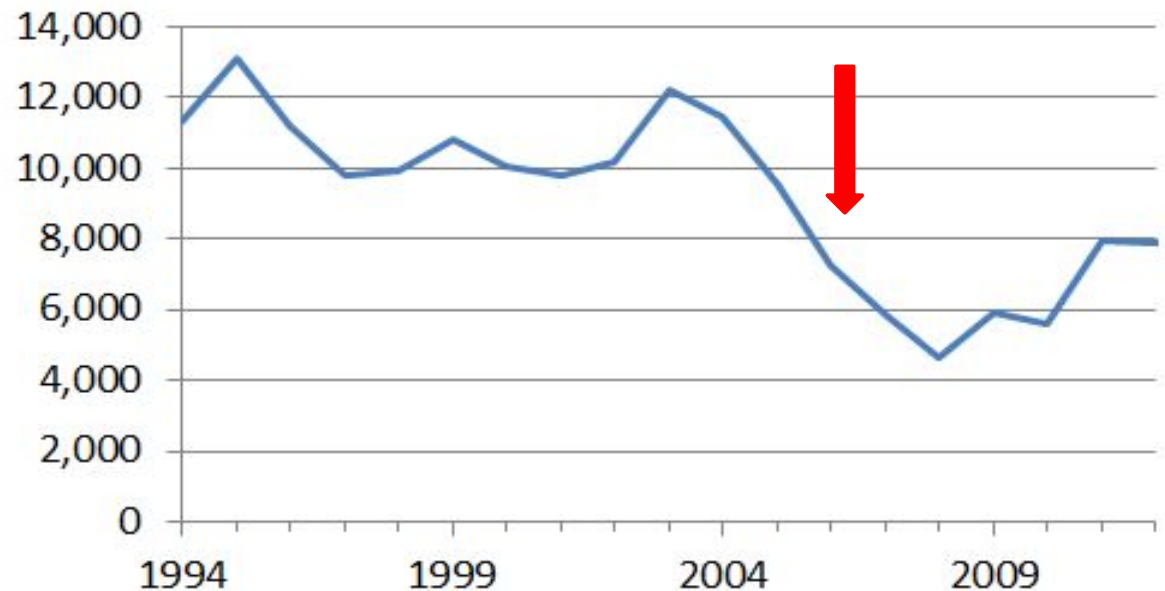
EXPLAIN THIS:

Walleye pollock abundance dramatically fell in the early 2000's, leading to a 40% drop in the quota for the largest single fishery in the US, and then rebounded.

Age-1 number (millions)



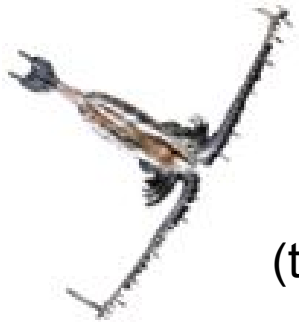
Age-3+
Biomass
(thousands t)



Ianelli, J.N., Barbeaux, S., Honkalehto, T., Kotwicki, S., Aydin, K. and Williamson, N., 2012. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. Anchorage, AK: North Pacific Fishery Management Council; 2009. *Assessment of the walleye pollock stock in the eastern Bering Sea for*, pp.49-148.

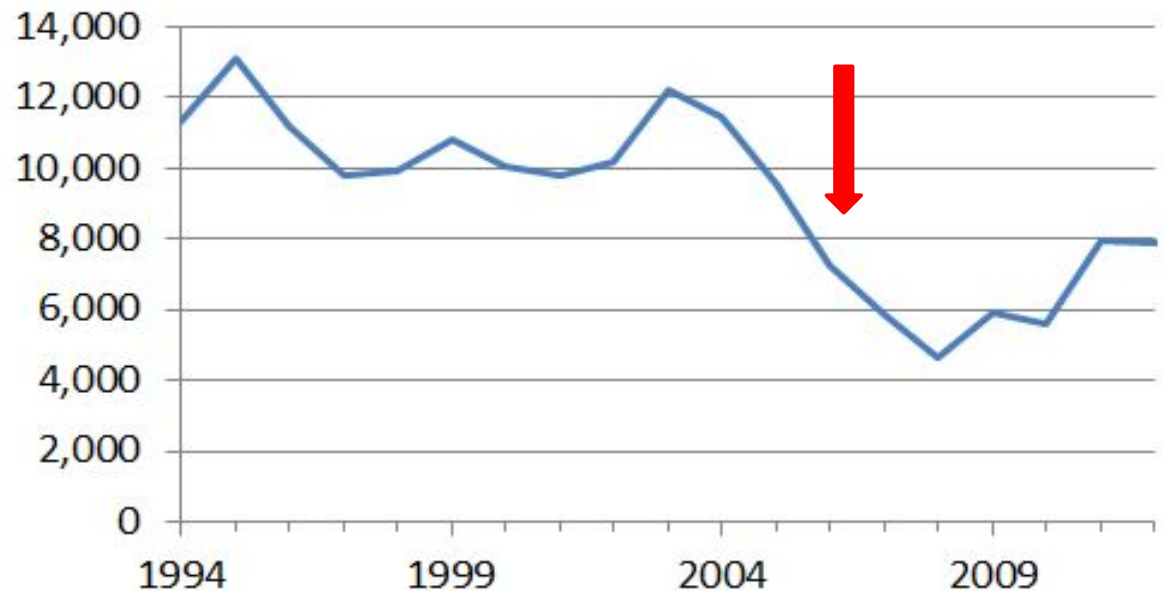
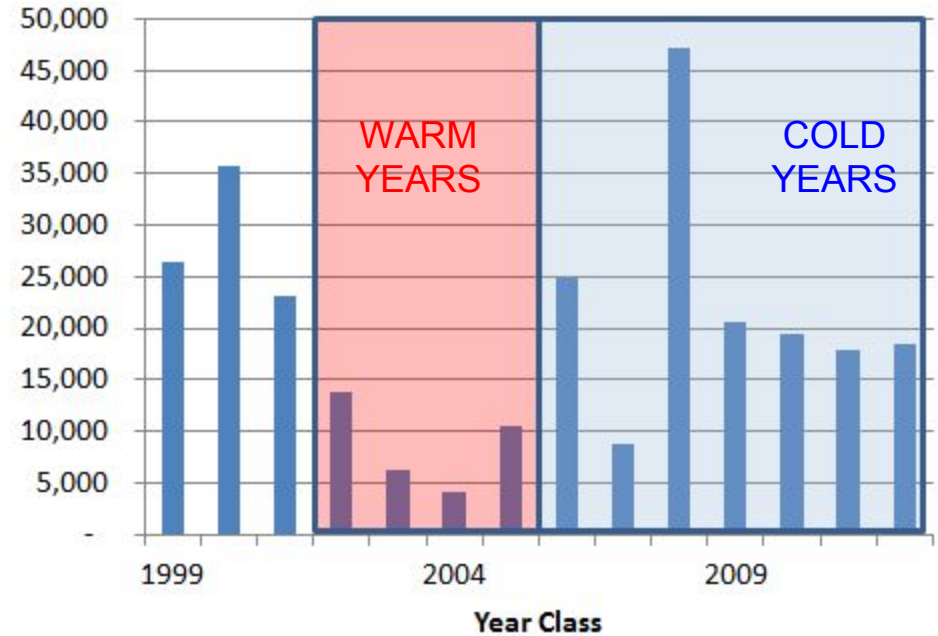
EXPLANATION:

Due to bloom timing, large crustacean zooplankton benefit from icy winters, providing prey for age-0 pollock to enter their first winter fat (and happy?)



Age-3+
Biomass
(thousands t)

Age-1 number (millions)



Heintz, R.A., Siddon, E.C., Farley, E.V. and Napp, J.M., 2013. Correlation between recruitment and fall condition of age-0 pollock (*Theragra chalcogramma*) from the eastern Bering Sea under varying climate conditions. *Deep Sea Research Part II: Topical Studies in Oceanography*, 94, pp. 150-156.

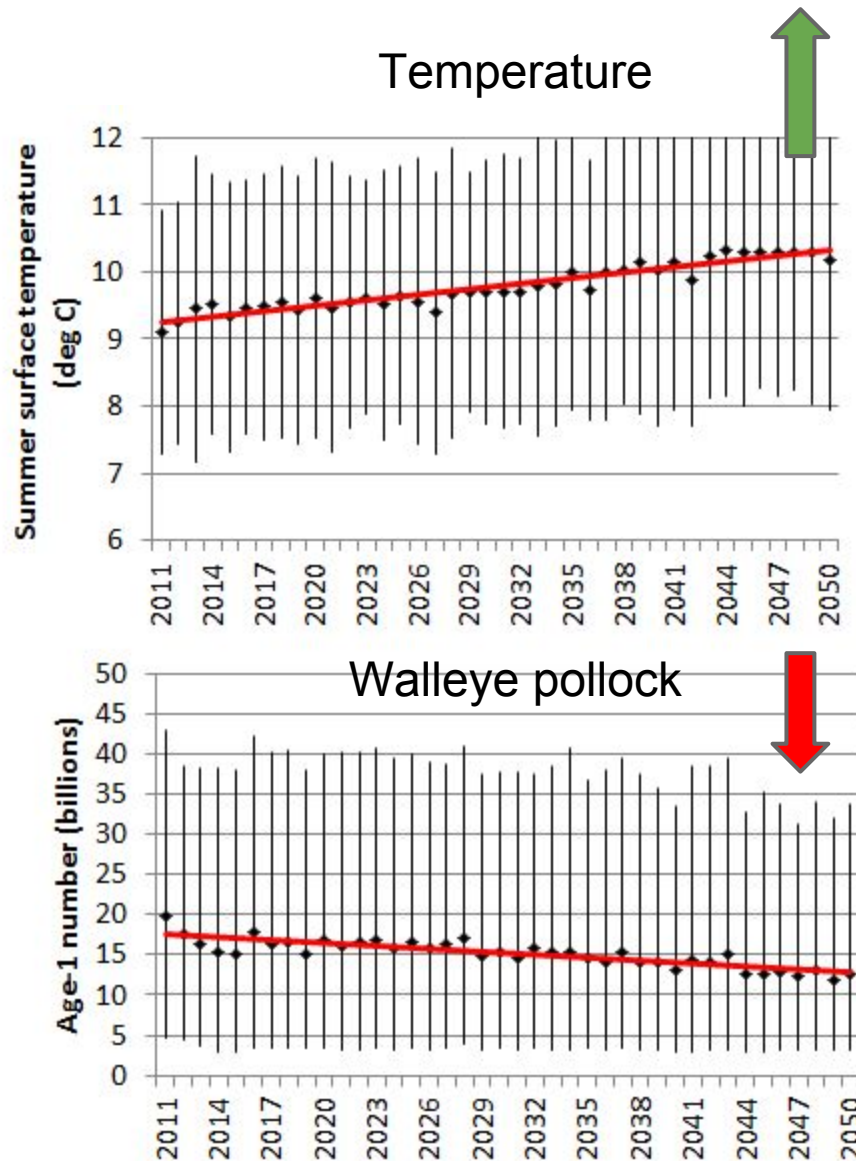


NOAA
FISHERIES

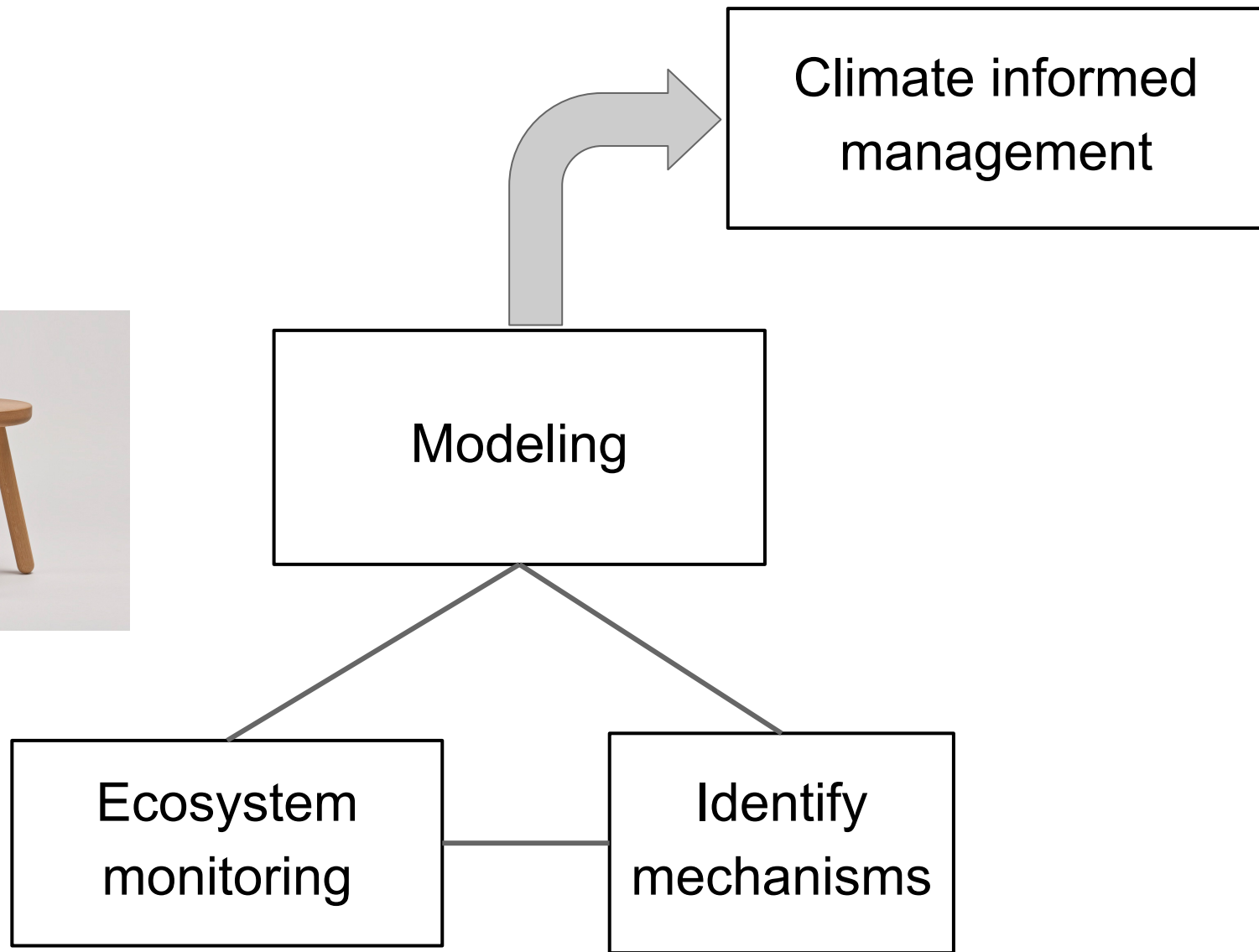
NOAA Fisheries Climate Science Strategy Highlights



Forecast pollock abundance



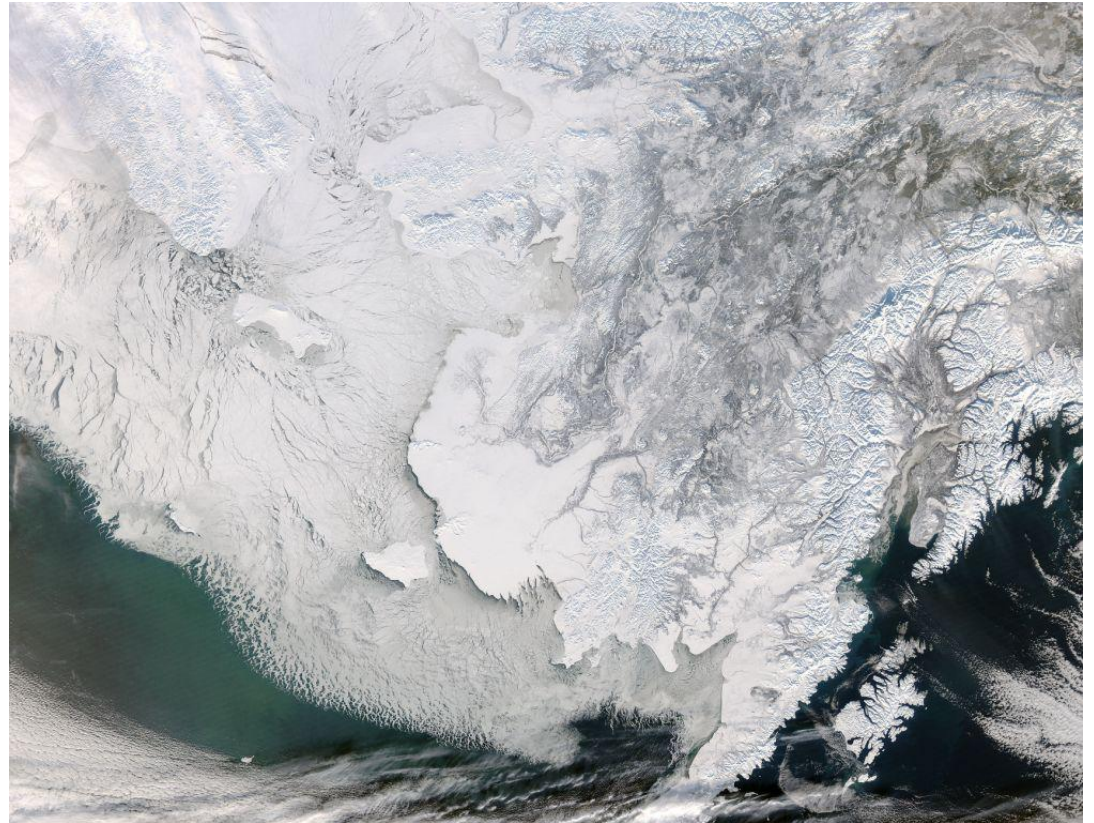
Mueter, F.J., Bond, N.A., Ianelli, J.N. and Hollowed, A.B., 2011. Expected declines in recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. *ICES Journal of Marine Science: Journal du Conseil*, p. fsr022.



Southeastern Bering Sea Climate Science Strategy

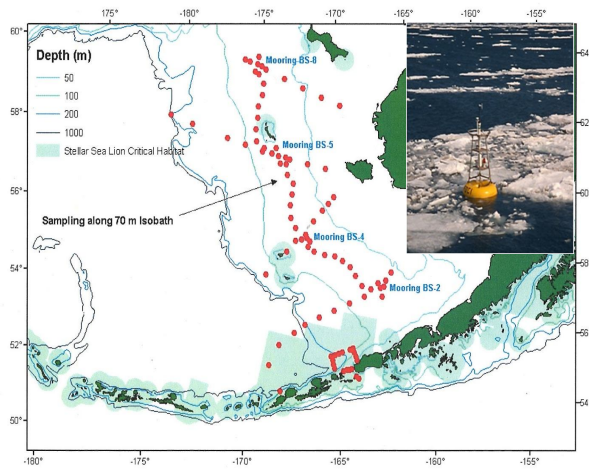
Assessment

Action Plan

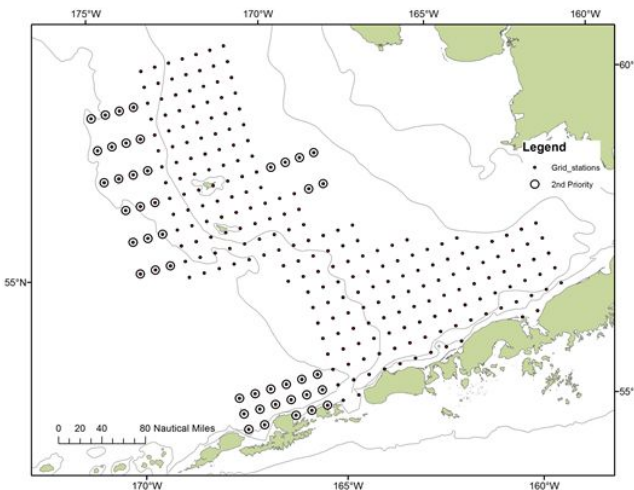


Monitor ecosystems

April-May & Sept-
Oct physics

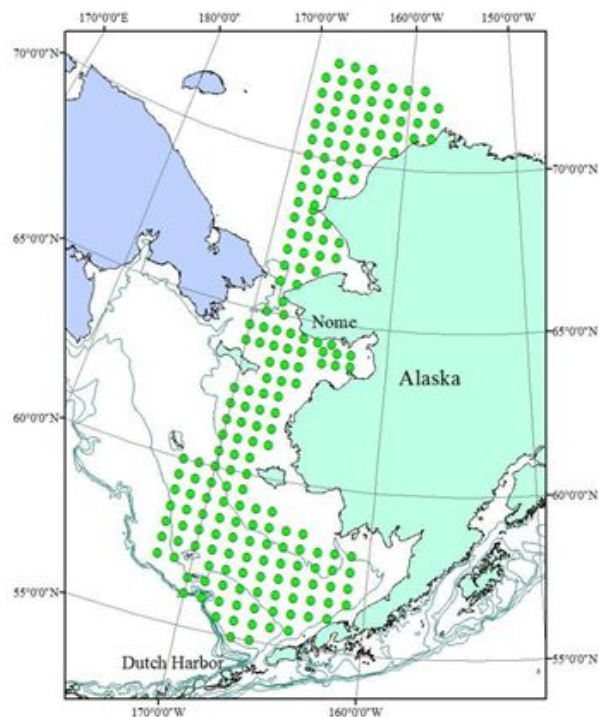


May, larval

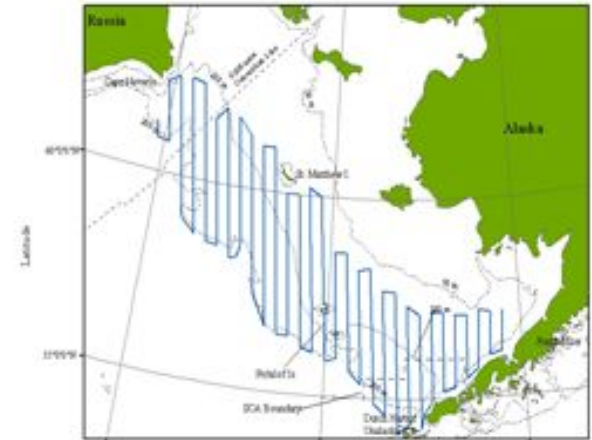


Seasonal surveys

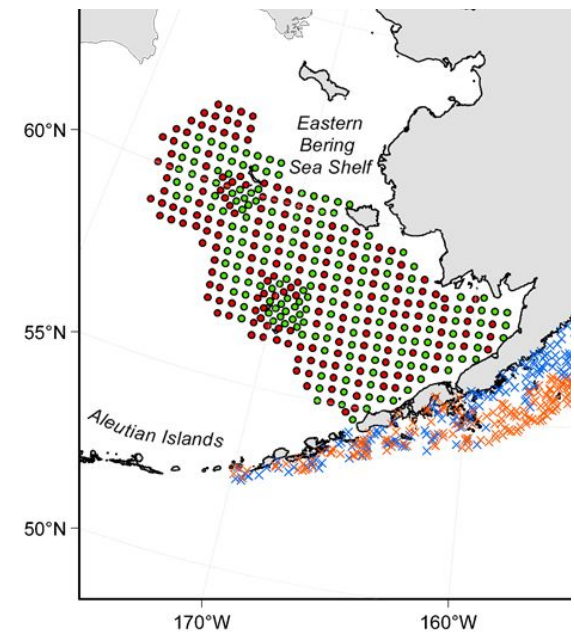
August-September,
age-0



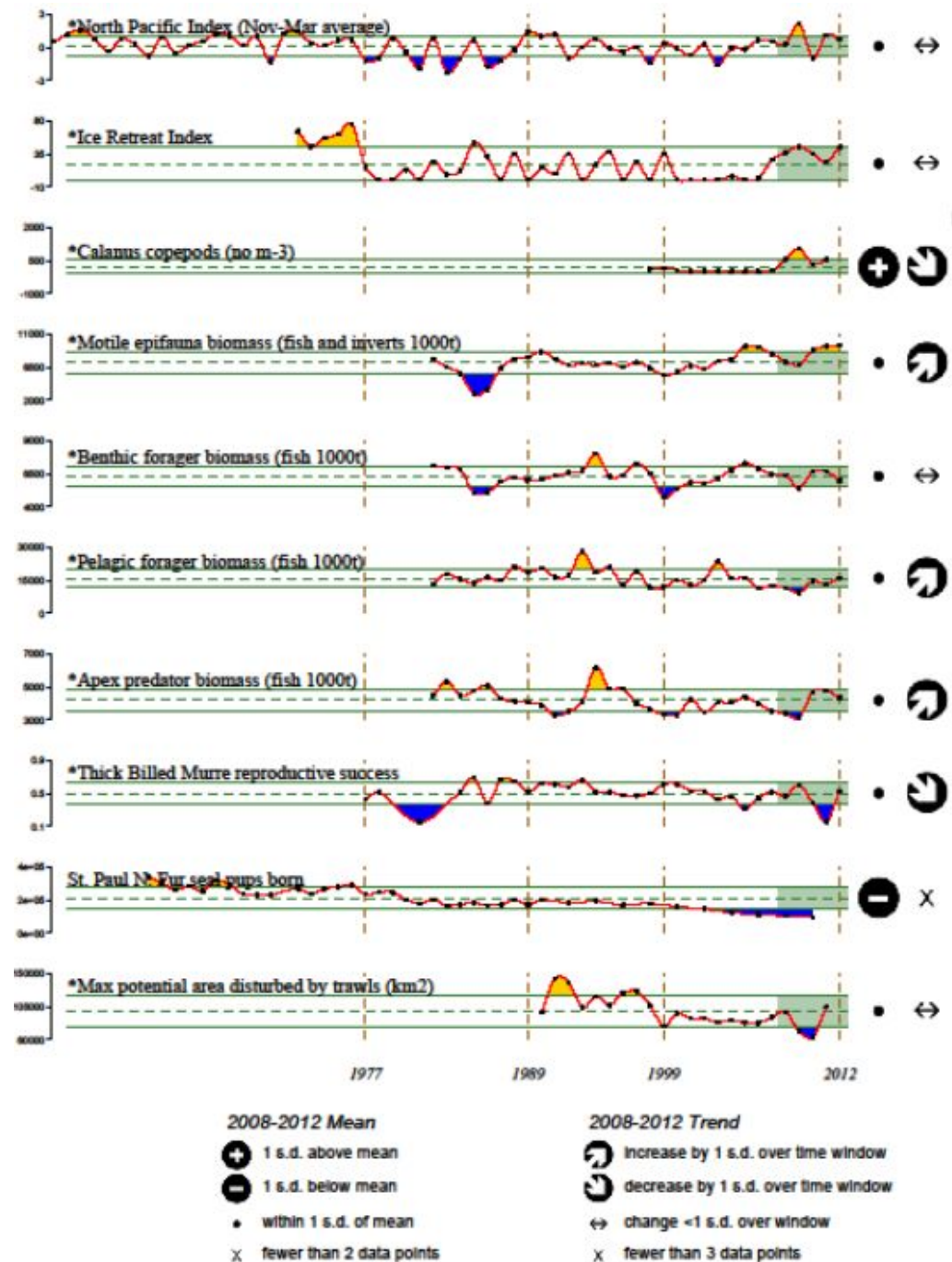
June-July, age-1



June-July, age-3+



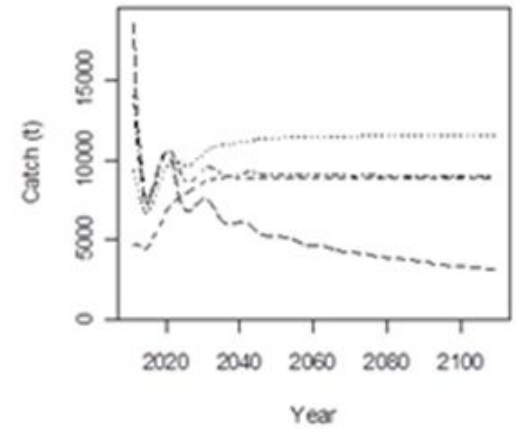
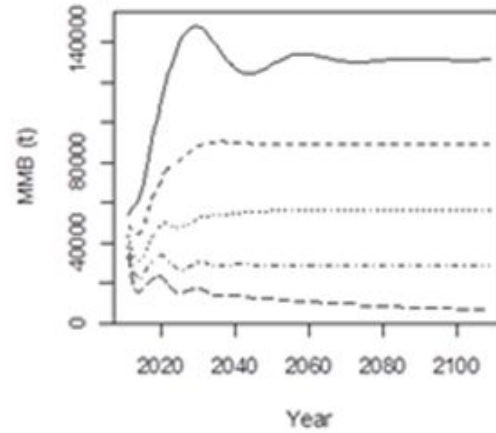
Alaska Marine Ecosystem Considerations



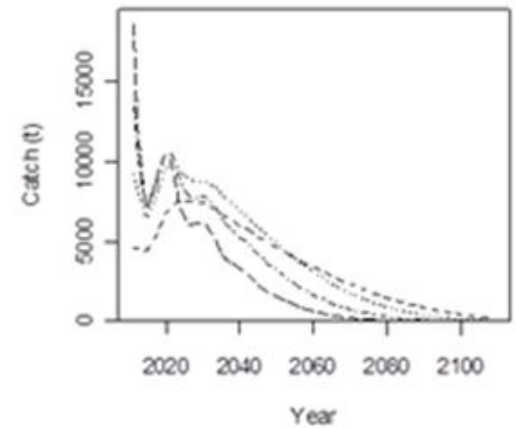
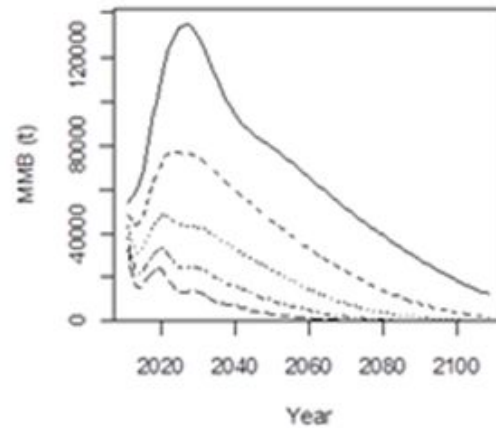
**Identify mechanisms
(process studies)**

Ocean acidification research

stock dynamics without OA



stock dynamics with OA



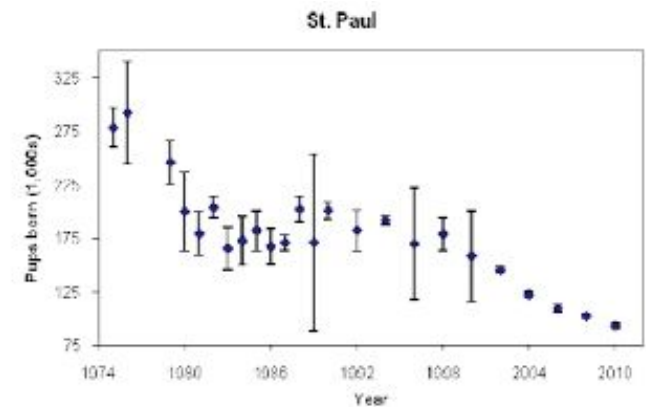
Long, W.C., Swiney, K.M. and Foy, R.J., 2013. Effects of ocean acidification on the embryos and larvae of red king crab, *Paralithodes camtschaticus*. *Marine pollution bulletin*, 69(1), pp. 38-47.

Punt, Poljak, Dalton, Foy. 2014. Evaluating the impact of ocean acidification on fishery yields and profits: The example of red king crab in Bristol Bay. *Ecol. Modeling*. 285: 39-53.



Fur seal research

- Pup production on the Pribilof Islands decreased by approximately 45% since 1998. Cause unknown, but may include direct and indirect effects of fishery competition as well as climate.
- Satellite telemetry in 2015 and 2016 is being used to understand effects during the winter migration and summer foraging.
- This project will link fine-scale changes in fur seal foraging behavior with measures of pollock distribution and abundance in real time.

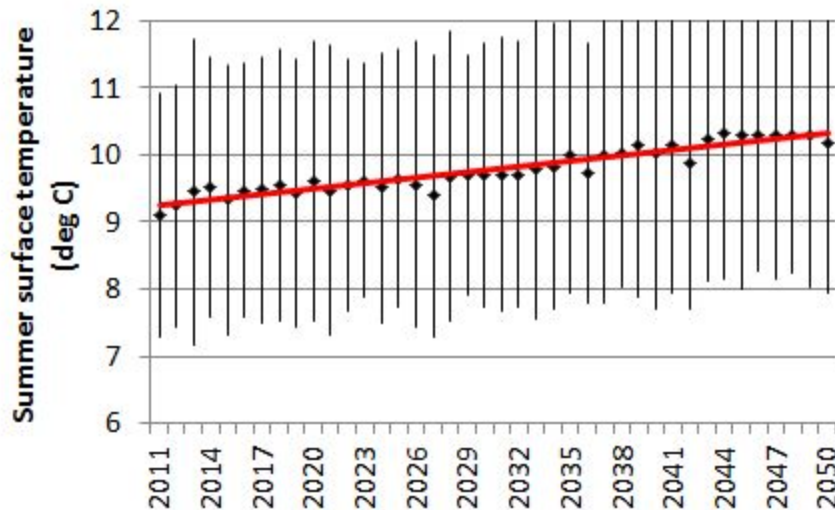


Allen, B.M., Angliss, R.P. and Wade, P. R., 2011. *Alaska marine mammal stock assessments, 2010*.

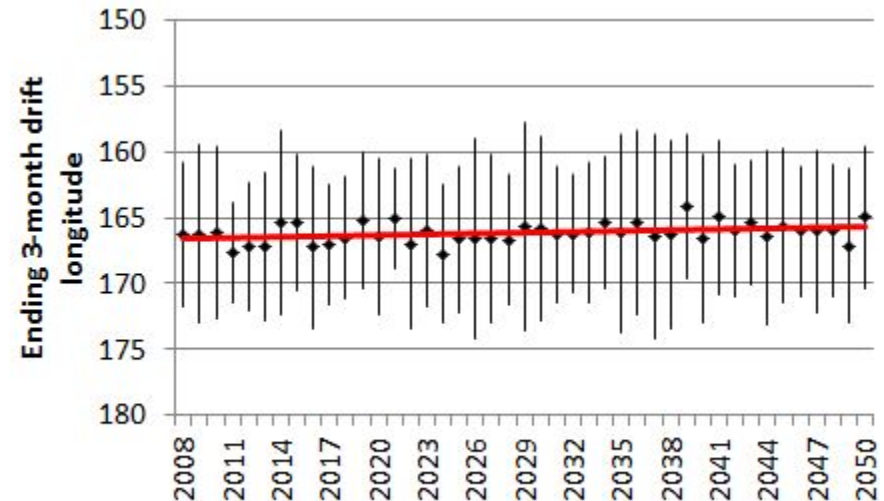
**Modeling:
Forecast models and
management strategy
evaluations (MSE)**

Ocean model projections

Temperature



Inshore transport



Mueter, F.J., Bond, N.A., Ianelli, J.N. and Hollowed, A.B., 2011. Expected declines in recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. *ICES Journal of Marine Science: Journal du Conseil*, p.fsr022.

Wilderbuer, T., Stockhausen, W. and Bond, N., 2013. Updated analysis of flatfish recruitment response to climate variability and ocean conditions in the Eastern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, 94, pp.157-164.

Alaska CLIMate Project

Anne Hollowed (AFSC, SSMA/REFM)
Kirstin Holsman (AFSC, REEM/REFM)
Alan Haynie (AFSC ESSR/REFM)
Stephen Kasperski (AFSC ESSR/REFM)
Jim Ianelli (AFSC, SSMA/REFM)
Kerim Aydin (AFSC, REEM/REFM)
Trond Kristiansen (IMR, Norway)
Al Hermann (UW JISAO/PMEL)
Wei Cheng (UW JISAO/PMEL)
André Punt (UW SAFS)

FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity



IPCC Scenarios (x3)

AR4 A1B
AR5 RCP 4.5
AR5 RCP 8.5

Global Climate Models (x 11)

ECHO-G (AR4 A1B)
MIROC3.2 med res. (AR4 A1B)
CGCM3-t47 (AR4 A1B)
CCSM4-NCAR- PO (AR5 RCP 4.5 & 8.5)
MIROCESM-C- PO (AR5 RCP 4.5 & 8.5)
GFDL-ESM2M*- PO (AR5 RCP 4.5 & 8.5)
GFDL-ESM2M*- PON (AR5 RCP 4.5 & 8.5)

Future Climate Scenarios



Climate-enhanced Biological Models

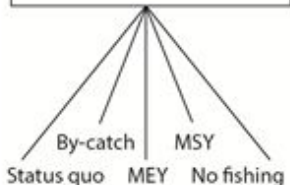
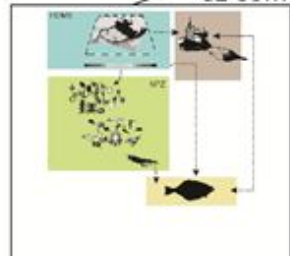


Fishing Scenarios



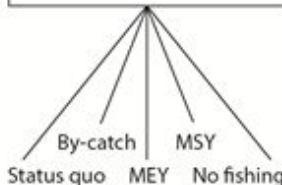
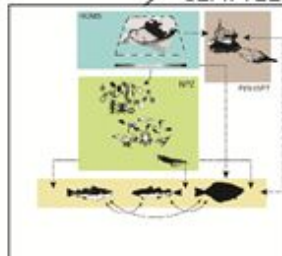
Bering Sea Models

CE-SSM



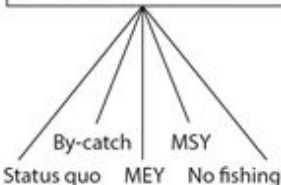
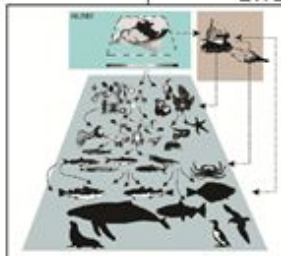
Harvest Control Rules (x5)

CEATTLE



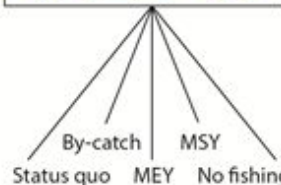
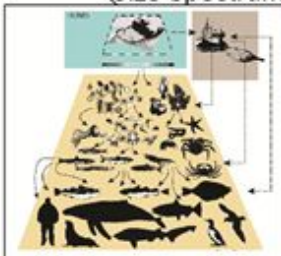
Harvest Control Rules (x5)

EwE



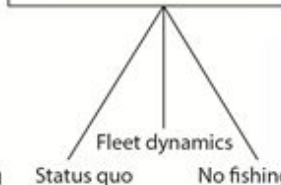
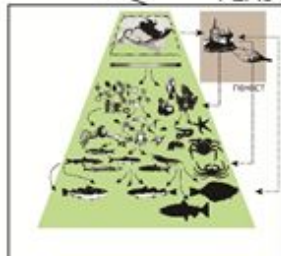
Harvest Control Rules (x5)

Size-Spectrum



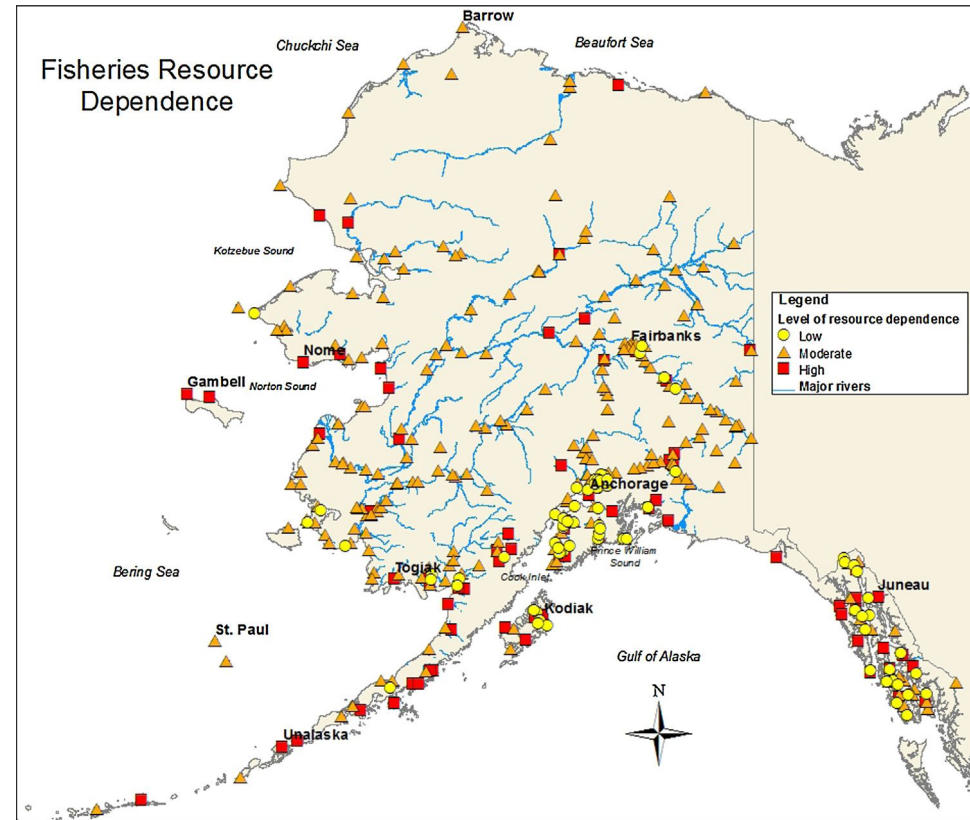
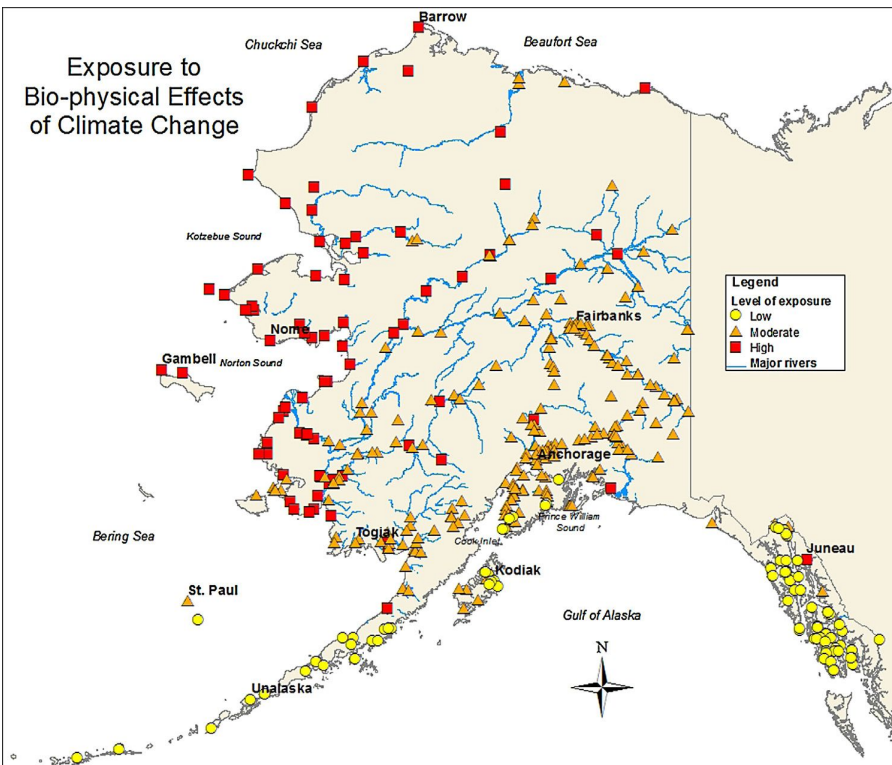
Harvest Control Rules (x5)

FEAST



Harvest Control Rules (x3)

Identify human community dependence on LMRs and effects of climate change.



Himes-Cornell, A. and Kasperski, S., 2015. Assessing climate change vulnerability in Alaska's fishing communities. *Fisheries Research*, 162, pp.1-11.

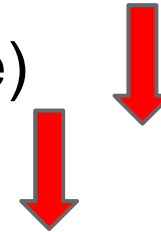
NPFMC Fisheries Ecosystem Plan. Approved by the Council in December 2015, the FEP includes a climate module that would:

- 1) synthesize current climate change project outcomes;
- 2) prioritize species for MSE evaluation; and
- 3) run MSEs on specific species and scenarios identified by the Council.

Challenge 1

Our ability to project future impacts is limited by our understanding of ecological processes. Understanding is sufficient for **only 3 of 21** comprehensively assessed stocks in the southeastern Bering Sea.

- Walleye pollock (through loss of sea ice)
- Red king crab (through increased CO₂)
- Northern rock sole



Mueter, F.J., Bond, N.A., Ianelli, J.N. and Hollowed, A.B., 2011. Expected declines in recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. *ICES Journal of Marine Science: Journal du Conseil*, p. fsr022.

Long, W.C., Swiney, K.M. and Foy, R.J., 2013. Effects of ocean acidification on the embryos and larvae of red king crab, *Paralithodes camtschaticus*. *Marine pollution bulletin*, 69(1), pp.38-47.

Wilderbuer, T., Stockhausen, W. and Bond, N., 2013. Updated analysis of flatfish recruitment response to climate variability and ocean conditions in the Eastern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, 94, pp.157-164.

Punt, Poljak, Dalton, Foy. 2014. Evaluating the impact of ocean acidification on fishery yields and profits: The example of red king crab in Bristol Bay. *Ecol. Modeling*. 285: 39-53.

Climate vulnerability assessment

A climate vulnerability assessment for the southeastern Bering Sea, which will **qualitatively assess** species vulnerabilities to climate change and provide guidance on research prioritization, currently is underway. The vulnerability assessment uses expert elicitation methods to quantify a species' exposure and sensitivity to expected climate change.

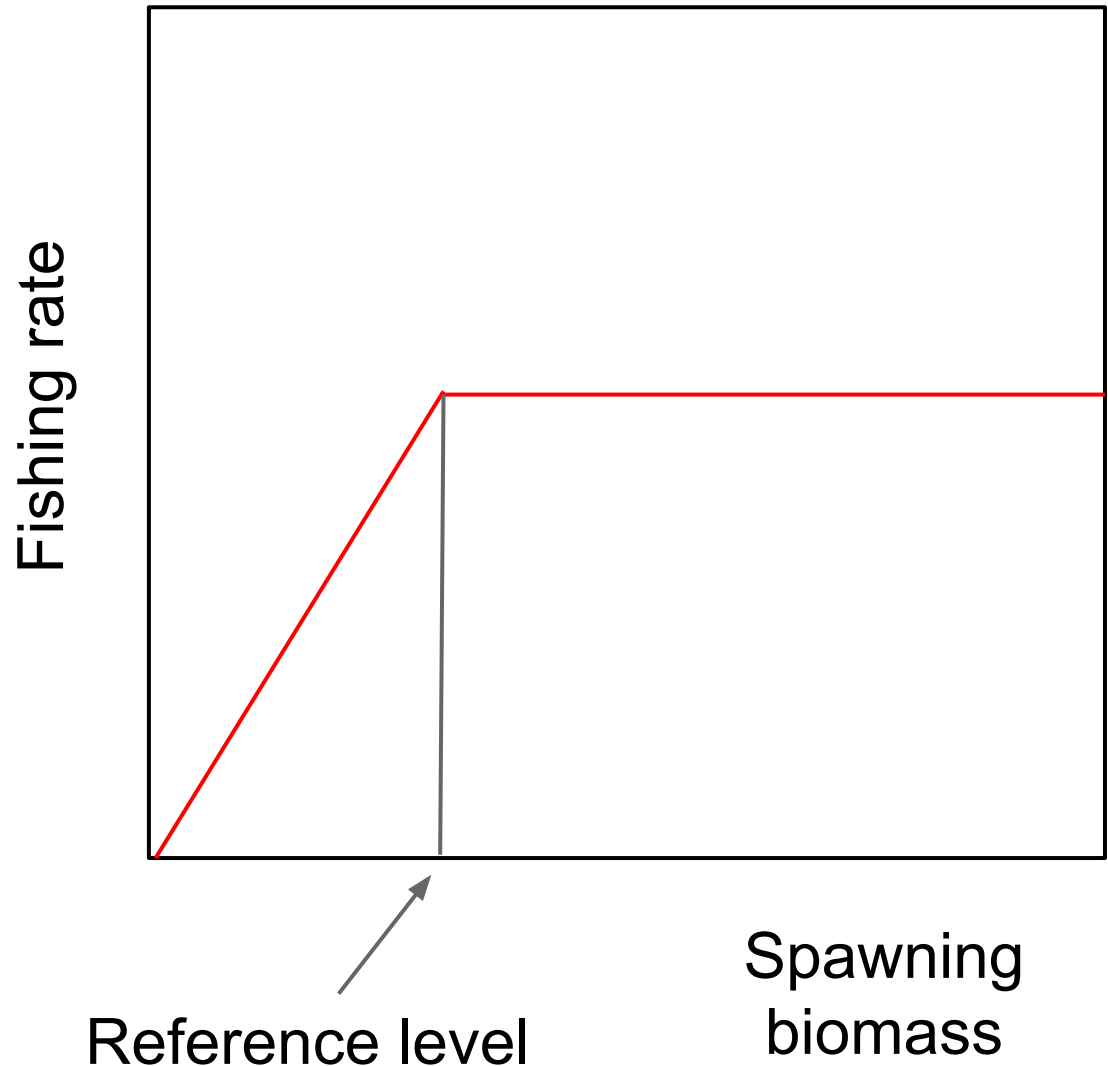
		Vulnerability Rank			
Sensitivity	Very High	Moderate	High	Very High	Very High
	High	Low	Moderate	High	Very High
	Moderate	Low	Moderate	Moderate	High
	Low	Low	Low	Low	Moderate
		Low	Moderate	High	Very High
		Exposure			

Recruitment Processes Alliance

- Research is conducted to understand processes affecting recruitment strength, including effects of climate.
- To date, understanding of these ecological mechanisms sufficient only to quantify effects on 3 fisheries (pollock, red king crab, northern rock sole).
- A significant fraction of AFSC resources are invested in this effort (e.g., ~15% of labor).

Challenge 2 (Obj. 3)

The NPFMC currently has a process that adapts harvest actions to changing measurements from fishery independent surveys. What is not well worked out is how and when the North Pacific Fishery Management Council should react to climate-induced reference point changes.



NMFS Climate Science Strategy



Southeastern Bering Sea
Climate Science Strategy

Southeastern
Bering Sea
Vulnerability
Analysis

Recruitment
Processes
Alliance

etc.

Most important steps to improve efforts to identify and adapt to climate change impacts on fisheries:

- Identify winners and losers and adjust management programs (i.e., catch share programs) as necessary
- Identify and monitor thresholds in ecosystem parameters that signal the need to adjust management strategies